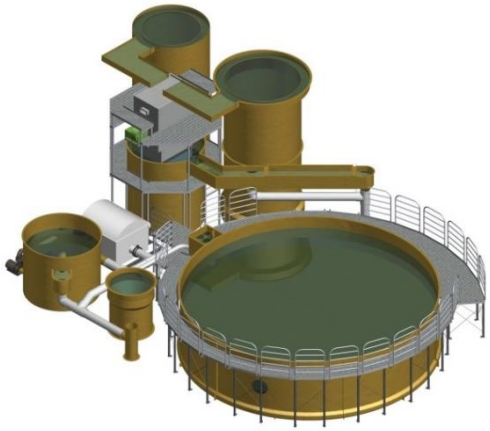
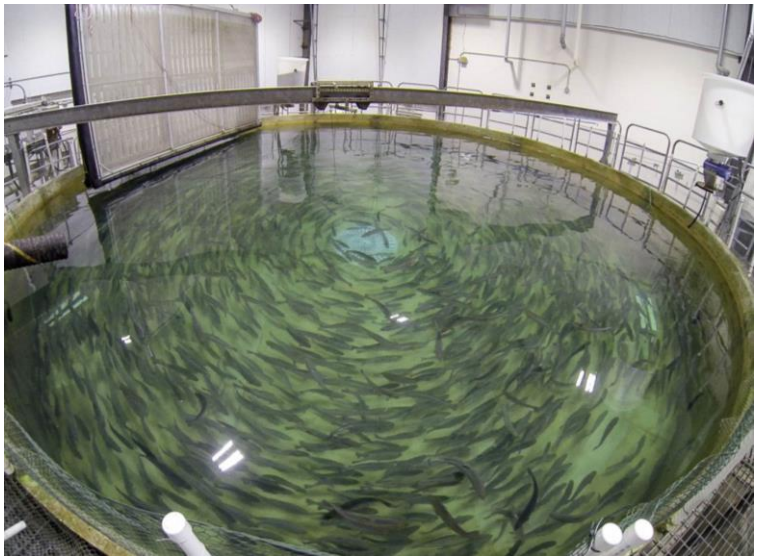
Is Continuous Peracetic Acid Dosing in RAS Really as Good as Ozone?





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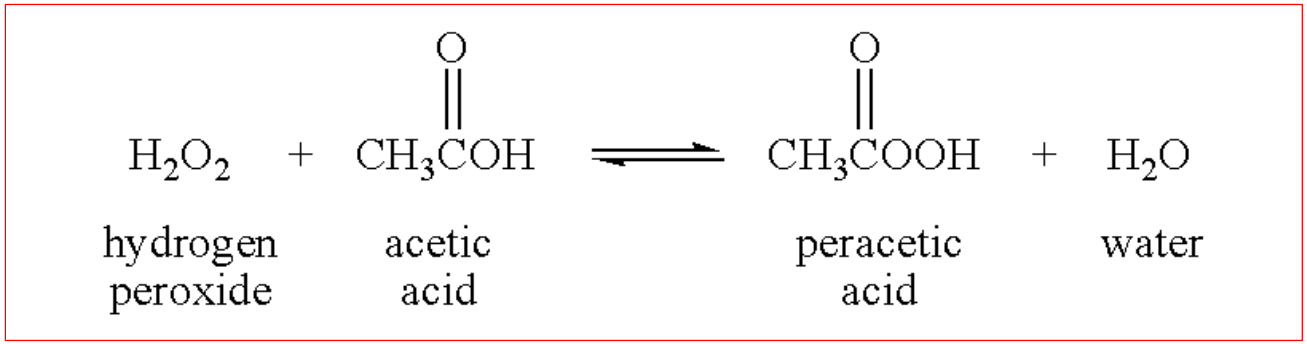
Aquaculture Innovation Workshop 2017
Vancouver, British Columbia

Background – Peracetic Acid



- Peracetic acid (PAA) is an antimicrobial agent used to disinfect surfaces
  - Agriculture industry, food establishments, medical industry, and other applications.

Advantages	Disadvantages
Antimicrobial Effects	Worker Safety? Highly Acidic/ Corrosive
Cost Effective ??	Not approved for use with fish in the US
Improved Fish Health/ Performance	Difficult to measure in water at low concentrations
Simple setup/dosing application	Water quality effects beyond microbial control ??

- PAA has been described as having "strong oxidizing potential and antimicrobial abilities similar to ozone." - *Pedersen et al. May/June 2015. Global Aquaculture Advocate*

Background - Ozone

- Ozone (O_3) is popularly used in RAS for water clarification
- Davidson et al. (2011) Aquacult. Eng. 45, 109-117 https://doi.org/10.1016/j.aquaeng.2011.04.001
- Good et al. (2017). Aquacult. Eng. 79, 9-16 https://doi.org/10.1016/j.aquaeng.2011.08.005

Advantages	Disadvantages
↓ Suspended Solids True Color Biochemical O_2 Demand Dissolved Metals Nitrite Bacteria Loads Sex steroids	Capital/ Operating Expense (generators, monitoring systems/controls, electrical)
↑ Oxygen Ultraviolet Transmittance	Operational Complexity
Improved Fish Performance	Potential Health/Safety Risk to Workers/Fish

Experimental Design

- We designed an experiment evaluating effects of continuous PAA dosing on RAS water quality and rainbow trout performance.

- We used VigorOx SP-15 from Peroxychem Inc.
  - Recently approved and registered by US EPA for surface disinfection of harvesting equipment and for cleaning/disinfection of fish tanks/systems

- Several theoretical doses were targeted at approximately monthly intervals:
  - 0.05, 0.10, 0.15, and 0.30 mg/L

VigorOx® SP-15 Antimicrobial Agent

EPA Registration No. 65402-3
EPA Est. No. 65402-NY-001

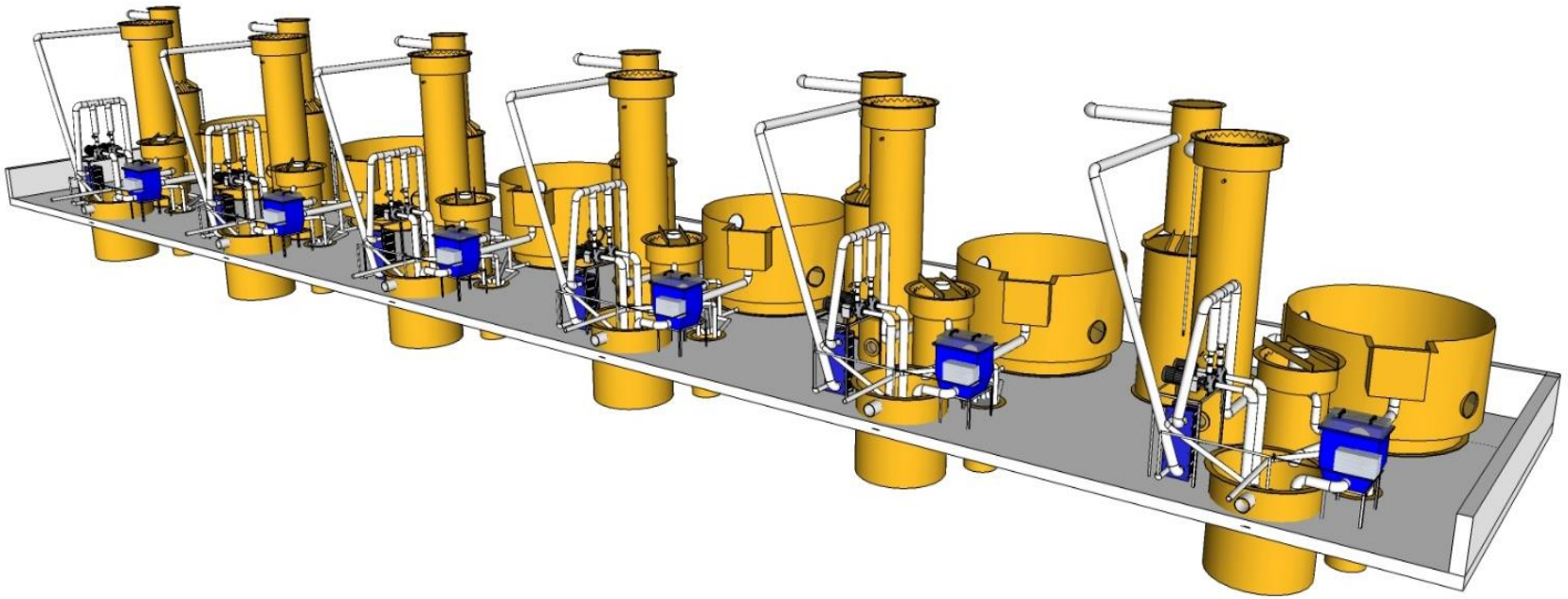
ACTIVE INGREDIENTS:	
Peroxyacetic Acid	15%
Hydrogen Peroxide	10%
OTHER INGREDIENTS:	75%
TOTAL:	100%

PeroxyChem

Manufactured by:
PeroxyChem, LLC
2005 Market St Ste 3200
Philadelphia PA 19103-7014

Experimental Design

- Utilized 6 replicated RAS (9.5 m^3)
  - Operated at hydraulic retention time = 2.7 days (99% recycle on a flow basis)
- Rainbow trout were counted into each RAS and given > 2 months acclimation prior to applying treatments
  - Mean weight = 407 ± 6 g to begin
- 3 RAS operated with semi-continuous PAA dosing
  3 RAS operated similarly but without PAA



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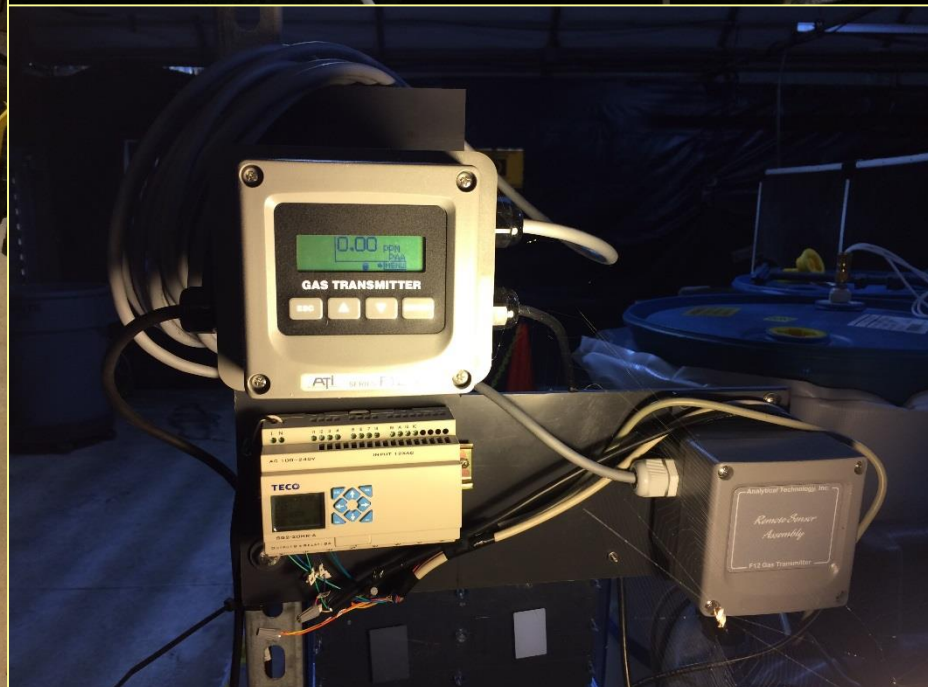
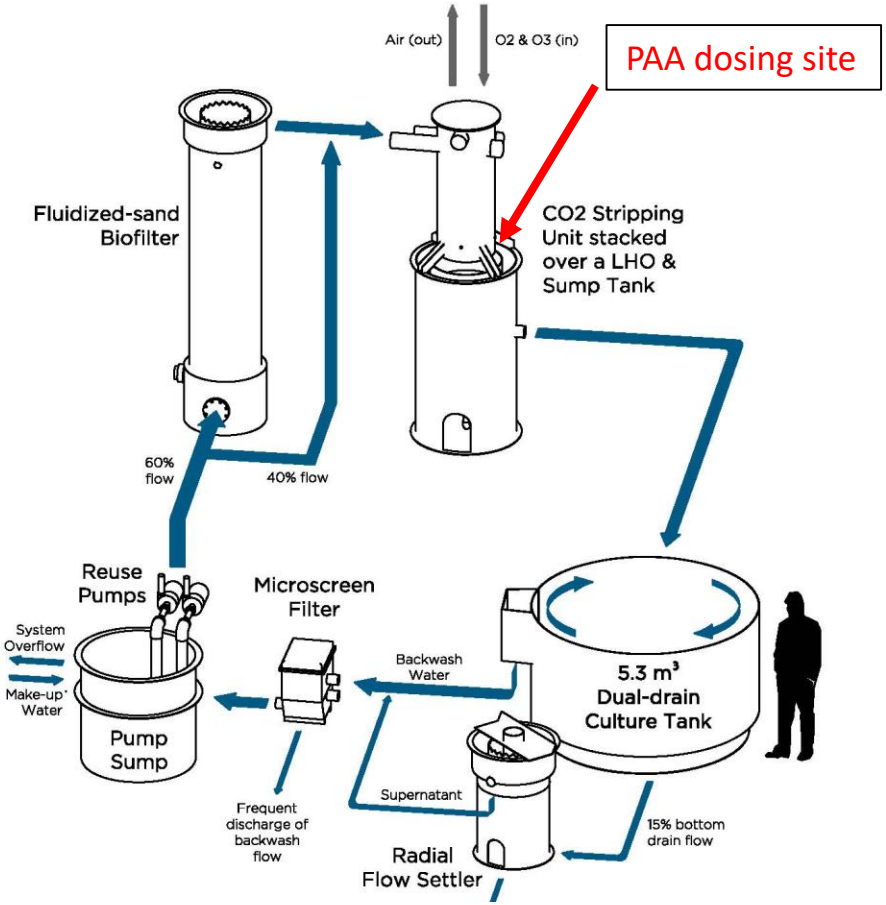
PAA Dosing & Monitoring



PAA Dosing

- PAA was introduced at the LHO water distribution chamber
  - Ideal location for mixing
  - After the biofilter
  - Same location as ozone injection



Drawing Courtesy Freshwater Institute Engineering Services

Controlled Water Quality

	1.6 kg feed per m^3 makeup water		1.4 kg feed per m^3 makeup water		1.5 kg feed per m^3 makeup water	
	0.10 mg/L PAA	Control	0.30 mg/L PAA	Control	Ozone	No Ozone
Temp. (°C)	13.0 ± 0.1	13.0 ± 0.1	13.6 ± 0.1	13.6 ± <0.1	15.1 ± 0.1	15.2 ± 0.2
pH	7.5 ± <0.1	7.5 ± 0.1	7.4 ± 0.1	7.4 ± 0.1	7.8 ± <0.1	7.8 ± <0.1
Alkalinity (mg/L)	159 ± 3	154 ± 7	141 ± 5	127 ± 5	196 ± 1	197 ± 1
CO_2 (mg/L)	11 ± <1	12 ± 1	14 ± 1	13 ± 1	8 ± 1	8 ± 1
DO (mg/L)	10.1 ± <0.1	10.0 ± 0.3	10.2 ± 0.3	10.1 ± <0.1	10.6 ± 0.3	10.2 ± 0.1
ORP * (mV)	271 ± 14	197 ± 8	290 ± 2	232 ± 11	293 ± 4	270 ± 2

- Robust control over key water quality variables at TCFFI
- Peracetic acid and ozone add some oxygen
- ORP was profoundly affected by PAA dosing

Nitrification

	1.6 kg feed per m^3 makeup water		1.4 kg feed per m^3 makeup water		1.5 kg feed per m^3 makeup water	
	0.10 mg/L PAA	Control	0.30 mg/L PAA	Control	Ozone	No Ozone
TAN (mg/L)	0.58 ± 0.03	0.64 ± 0.05	0.59 ± 0.03	0.68 ± 0.04	0.17 ± 0.01	0.20 ± 0.01
NO_2N (mg/L)	0.19 ± 0.03	0.11 ± 0.03	0.09 ± 0.06	0.05 ± <0.01	0.01 ± <0.01	0.01 ± 0.01
NO_3N (mg/L)	64 ± 2	69 ± 3	54 ± 3	64 ± 2	50 ± 3	50 ± 2

- PAA did not inhibit nitrification
- At higher loading ozone has been found to oxidize nitrite
  - Davidson et al. (2011)

Water Clarity and Solids

	1.6 kg feed per m^3 makeup water		1.4 kg feed per m^3 makeup water		1.5 kg feed per m^3 makeup water	
	0.10 mg/L PAA	Control	0.30 mg/L PAA	Control	Ozone	No Ozone
$cBOD^5$ (mg/L)	10.6 ± 4.0	8.6 ± 3.5	11.7 ± 4.7	11.7 ± 1.7	1.07 ± 0.03	1.22 ± 0.03
TSS (mg/L)	16.1 ± 8.0	11.6 ± 4.4	9.3 ± 2.6	7.7 ± 0.7	1.5 ± 0.2	1.7 ± 0.1
True * Color (Pt-Co units)	32 ± 2	40 ± 2	18 ± 1	23 ± 2	3.7 ± 0.3	20 ± 1
UVT (%)	71 ± 2	69 ± 1	79 ± 1	78 ± 1	91 ± 0.4	79 ± 0.8

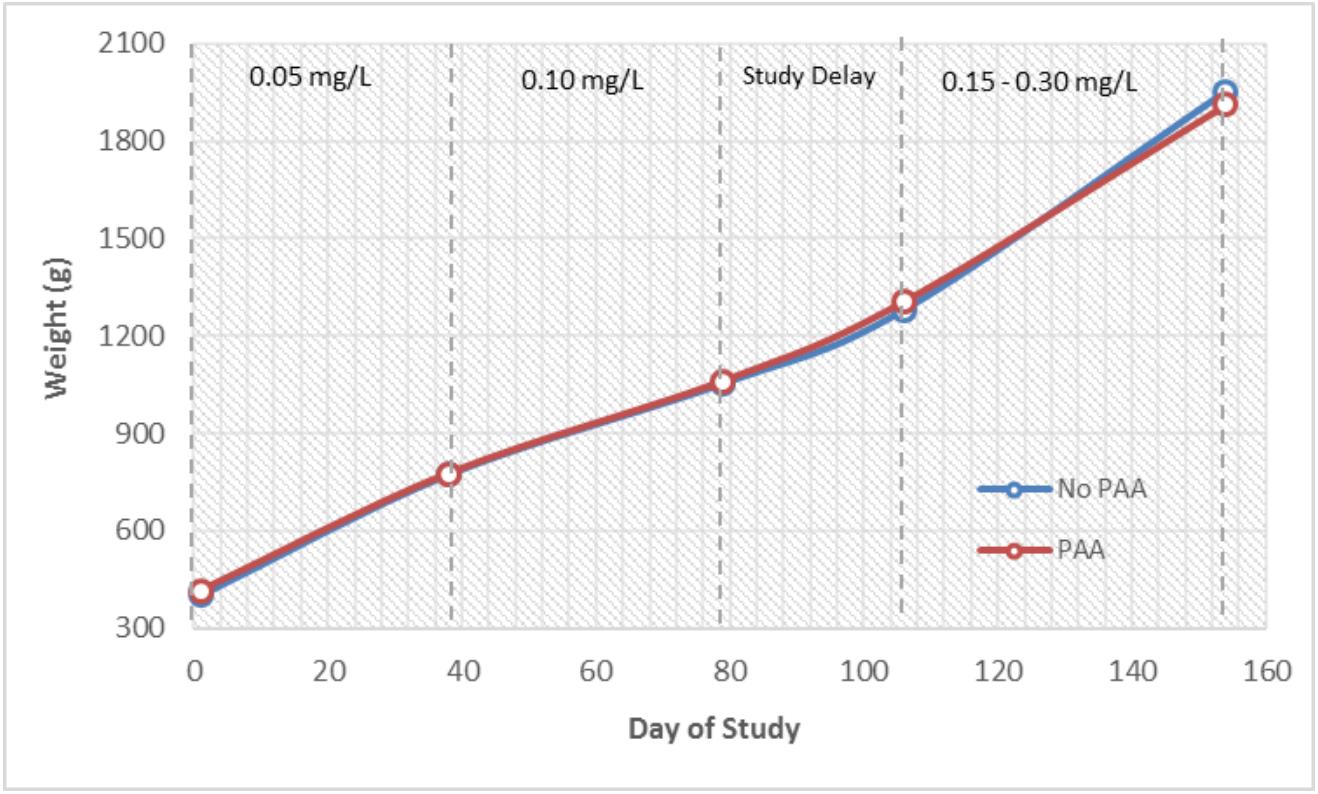
- True color reduced 20 and 22% for 0.10 and 0.30 mg/L PAA doses, respectively and by 82% during previous ozone study with similar loading
- Ultraviolet transmittance not affected by PAA but increased 15% with ozone
- Davidson et al. (2011) showed reductions of 53% BOD, 61% TSS and 92% true color and 37% increase in UVT when feed loading was 3.9 kg feed /m^3 makeup water

Microbial Water Quality

	1.6 kg feed per m^3 makeup water		1.4 kg feed per m^3 makeup water		1.5 kg feed per m^3 makeup water	
	0.10 mg/L PAA	Control	0.30 mg/L PAA	Control	Ozone	No Ozone
Heterotrophic Bacteria (cfu/mL)	2.5×10^3	5.2×10^3	4.0×10^3	9.6×10^2	4.7×10^2	4.9×10^2
Total Coliform Bacteria (cfu/100 mL)	1.4×10^4	7.4×10^4	7.4×10^3	4.7×10^4	NA	NA

- PAA becoming popular tool for microbial control and water treatment in European aquaculture
- No statistical differences heterotrophic or total coliform bacteria counts present study
- Liu et al. (2017) showed that pulse PAA dosing caused less biofilm formation compared to continuous dosing
- Davidson et al. (2011) showed a 2000-fold reduction in heterotrophic bacteria when using low-dose ozone in RAS with 3.9 kg/m^3 feed loading

Trout Performance



	PAA	No PAA
End Weight (g)	1911 ± 30	1954 ± 30
Thermal Growth Coefficient	2.4 ± 0.01	2.5 ± 0.02
FCR	1.6 ± <0.1	1.7 ± 0.1
Condition Factor	2.4 ± <0.1	2.4 ± <0.1

Off-flavor

Off-flavor Compound	Sample	PAA (0.30 mg/L)	Control
Geosmin (ng/L)	Water	11 ± 5	9 ± 5
Geosmin (ng/L)	Biofilm	185 ± 133	236 ± 157
Geosmin (ng/kg)	Fillets	3546 ± 2057	2431 ± 1182
MIB (ng/L)	Water	3 ± 1	2 ± 0
MIB (ng/L)	Biofilm	14 ± 7	23 ± 7
MIB (ng/kg)	Fillets	55 ± 10	27 ± 5

- No significant difference in off-flavor concentrations at any PAA dose, including highest theoretical concentration (0.30 mg/L)

Conclusions/ Outcomes

- Peracetic acid is relatively cheap. Cost per day was $0.418. We only used one 55-gal drum over five months at varying dosing rates.
- PAA did not negatively affect rainbow trout growth or health and did not harm biofilter function.
- PAA is not a viable replacement for ozone for water quality control in RAS.
- PAA is a promising compound for use in RAS as a water disinfectant to manage fish health problems.
- Oxidative reduction potential increased according to PAA dose indicating potential to use ORP as an on/off control for PAA dosing.
- A safe and effective method for PAA storage and dosing was developed.

Acknowledgements

- Research supported by the Agriculture Research Service of the United States Department of Agriculture, under Agreement No. 59-1930-5-510.

- Opinions, conclusions, and recommendations are of the authors and do not necessarily reflect the view of the USDA.

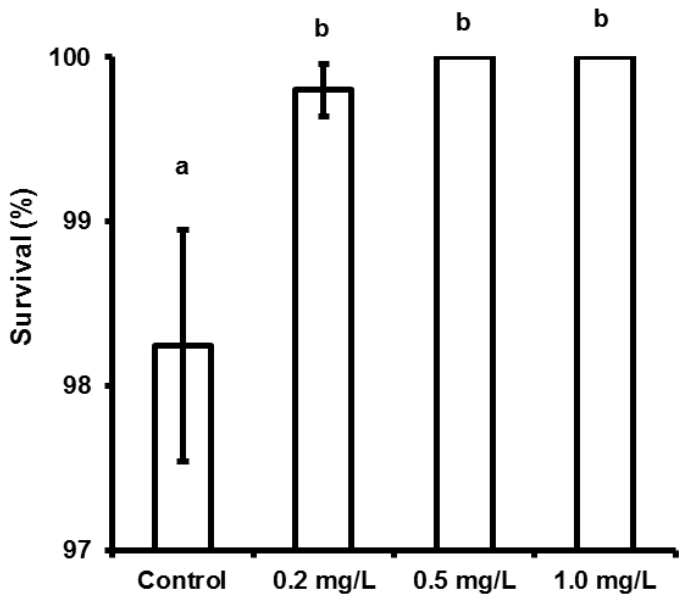
- All experimental protocols were in compliance with Animal Welfare Act (9CFR) and approved by the Freshwater Institute Animal Care and Use Committee.

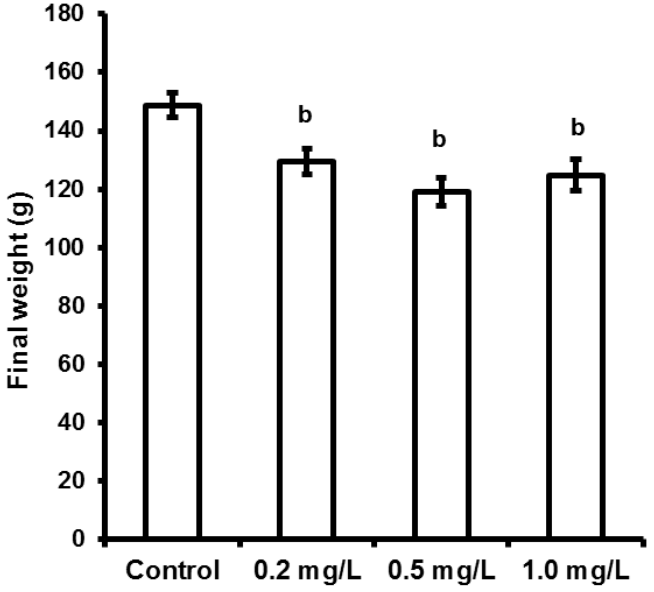
- Special thanks to Karen Schroyer, Natalie Redman, Megan Murray, and Ella Bushman for water quality analyses, to Dewayne Harries for technical support related to off-flavor analyses, to Lauren Cheeks and Joseph Beach for fish husbandry and project assistance, and to Christine Lepine for data entry and organization.

Materials & Methods

- 12 experimental-scale RAS
- 2,400 ~90g Atlantic salmon parr from USDA-ARS
- IC vaccination
- 6 weeks daily pulse treatments: 0.2, 0.5, and 1.0 mg/L PAA
- Monitored: mortality, *Saprolegnia* spp. water counts, TAN removal efficiency, observations of fungus
- Histopathology; final welfare assessment

Supplementary – Effect of PAA on Post-vaccination *Saprolegnia* spp.





Pathology	Odds ratio (95% C.I.)	*p*-value
Fin erosion	0.929 (0.697 – 1.24)	0.618
Hemorrhage	0.910 (0.720 – 1.15)	0.426
Fungus	**0.074 (0.015 – 0.372)**	**0.002**